

## Oil Well Perforator Liner With High Proportion Of Heavy Metal

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**OILWELL PERFORATOR LINER WITH HIGH PROPORTION OF HEAVY METAL****TECHNICAL FIELD**

A shaped charge suitable for use in a perforating tool for a subterranean well is described. The invention relates particularly to an improved shaped charge liner constructed from powdered heavy metal and binder material with a high proportion of tungsten or similar heavy metal.

**BACKGROUND OF THE INVENTIONS**

A subterranean gas or oil well typically begins with a hole bored into the earth, which is then lined with joined lengths of relatively large diameter metal pipe. The casing thus formed is generally cemented to the face of the hole to give the well integrity and a path for producing fluids to the surface. Conventionally, the casing and cement are subsequently perforated with chemical means, commonly explosives, in one or more locations of the surrounding formation from which it is desired to extract fluids. In general, the perforations extend a distance into the formation. One of the problems inherent in the art is to maximize the depth of penetration into the formation.

Explosive shaped charges known in the art generally have a substantially cylindrical or conical shape and are used in various arrangements in perforating tools in subterranean wells. Generally, a tubular perforating gun adapted for insertion into a well is used to carry a plurality of shaped charges to a subsurface location where perforation is desired. Upon detonation of the shaped charges, explosive jets emanate from the shaped charges with considerable velocity and perforate the well casing and surrounding formation.

Liners of shaped charges have commonly been designed in an effort to maximize penetration depth. Various metals have been used. Solid metal liners have the disadvantage of

introducing metal fragments into the formation, detracting from the effectiveness of the perforation. Compressed powdered metal liners have sometimes been used. Such liners disintegrate upon detonation of the shaped charge, avoiding the problems associated with metal fragments. It is known in the art that heavy metals are particularly suited for use in liners.

5 Generally, the heavy metal is combined with one or more other metals with suitable binding characteristics to form rigid liners through very high compression of the metal powders. One of the principal problems in the art has been the attempt to increase the heavy metal content of liners. Such attempts are outlined in United States Patent Numbers 5,656,791 and 5,814,758, which are incorporated herein for all purposes by this reference.

10 The success in the art of producing compressed powdered heavy metal liners has been limited by efforts to identify suitable binding agents among elemental metals and alloys. Previous attempts in the art have increased tungsten content to approximately 80 percent. The present invention employs binder materials in combination with tungsten powder to produce an improved shaped charge compressed liner with a tungsten content higher than previously known  
15 in the art.

### SUMMARY OF THE INVENTIONS

The inventions provide shaped charge apparatus for use in a subterranean well. In general, the inventions contemplate an improved liner for a shaped charge constructed from a  
20 combination mixture of a high proportion of powdered heavy metal and selected binder metal.

According to one aspect of the invention, a mixture of powdered tungsten and powdered metal binder is formed into a rigid shaped charge liner having a tungsten content in a range of between approximately 90 % to 99.98% by weight.

According to another aspect of the invention, a liner having a tungsten content in a range of between approximately 90 % to 99.98% by weight is constructed of a binder metal-coated heavy metal powder formed into a rigid body.

According to still another aspect of the invention, a liner for a shaped charge is  
5 constructed from a mixture of powdered tungsten and powdered metal binder blended with a binder metal-coated heavy metal powder formed into a substantially conical rigid body. The resulting liner having a tungsten metal content in a range of between approximately 93 % to 99.98% by weight.

## 10 BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are incorporated into and form a part of the specification to illustrate several examples of the present inventions. These drawings together with the description serve to explain the principals of the inventions. The drawings are only for the purpose of illustrating preferred and alternative examples of how the inventions can be made and  
15 used and are not to be construed as limiting the inventions to only the illustrated and described examples. The various advantages and features of the present inventions will be apparent from a consideration of the drawings in which:

FIGURE 1 is a side elevation view of an example of an axially symmetrical shaped charge in accordance with the invention; and

20 FIGURE 2 is cross-sectional view taken along line 2-2 of Figure 1 showing an example of an embodiment of a shaped charge in accordance with the inventions.

## DETAILED DESCRIPTION

The present inventions are described by reference to drawings showing one or more examples of how the inventions can be made and used. In these drawings, reference characters  
25 are used throughout the several views to indicate like or corresponding parts. The drawings are

not necessarily to scale and the proportions of certain parts have been exaggerated to better illustrate details and features of the invention.

The apparatus and methods of the invention are shown generally in Figures 1 and 2. A conically symmetrical shaped charge 10 is shown. The shaped charge is sized for a perforating gun commonly used to perforate subterranean wells and formations. Typically, a plurality of shaped charges are arranged in a substantially helical pattern on the perforating gun assembly. The exact size and shape of the shaped charge or the configuration of the perforating gun are not critical to the invention. The shaped charge 10 is enclosed by a case 12. Generally, the case 12 is substantially cylindrical or conical. As used herein, the term “conical” is used to refer to shapes substantially conical or in the form of frustum or truncated cone. Again, the exact shape of the case is not critical to the invention. In use, the perforating gun (not shown) is placed in a subterranean location where perforation of the well casing and/or formation is desired, herein designated the target 14. The shaped charge has a muzzle 16, which is oriented toward the target 14, and an opposing closed end 18.

Now referring primarily to Figure 2, the case 10 is shown in cross section, revealing that the closed end 18 has a relatively small aperture 20 connected to a detonation cord 22. The detonation cord 22 is typically operably connected to a detonation circuit system (not shown) known in the art. The case 10 contains a predetermined amount of high explosives 24 generally known in the arts, for example, RDX, HMX, HNS, CL-20, NONA, BRX, PETN, or PYX. A substantially conical liner 26 is disposed inside the case 12 between the high explosive 24 and the muzzle 16, preferably such that the high explosive 24 fills the volume between the casing 12 and the liner 26. The liner is typically affixed to the case with adhesive (not shown), but a retaining ring or spring may also be used. Upon detonation of the high explosive 24, the liner 26 disintegrates and the liner material is propelled through the muzzle 16 into the target 14. As known to those skilled in the arts, it is advantageous for the

liner to disintegrate upon detonation of the high explosive and to have the maximum possible mass and velocity.

Further referring primarily to Figure 2, the liner 26 is preferably constructed by compressing a powdered heavy metal and powdered metal binder material under very high pressure to form a rigid body. The process of compressively forming the liner from powdered heavy metal and powdered metal binder is understood by those skilled in the arts. Other methods of fabrication, such as sintering may be used. The powdered heavy metal is preferably tungsten, but may be another metal or mixture of metals. Metals with high density, high ductility, and capable of achieving high acoustic velocity are preferred. Metals chosen from the group tungsten, tantalum, hafnium, and copper are particularly suitable. Although other metals may be used, cost is often a major factor. Preferably, the percentage of heavy metal, preferably tungsten, in the liner is within a range of approximately 99.0 % to 99.98 % by weight. Optionally, percentages within a range of approximately 90.0 % to 99.98 % may be used.

The binder metal is chosen for its ability to bind together under high levels of compression. Typically, metals chosen from the group copper, lead, zinc, tin, and bismuth are used. The percentage of powdered binder metal, preferably lead, in the mixture is preferably within a range of approximately 0.02% to 1.0% by weight, although percentages within a range of approximately 0.02 % to 10.0 % may also be used. Optionally, mixtures of binder metals or alloys such as those containing relatively high levels of tin or zinc may be used.

Optionally, the liner 26 may also contain approximately 0.2% to 1.0% lubricant by weight. Powdered graphite is a preferred lubricant known in the arts, although oils may also be used. Some oils such as linseed oil or tung oil, or other unsaturated organic compounds as disclosed in United States Patent Number 4,794,990, which is incorporated in its entirety for all purposes by this reference, are thought to be helpful in preventing corrosion of the liner.

The presently most preferred embodiment of the invention uses a liner 26 constructed from a heavy metal powder coated with a binder metal, a binder metal-coated heavy metal powder compressively formed into a rigid body. The process of coating the heavy metal powder with a binder metal is understood by those skilled in the arts. The heavy metal powder, coated with binder metal, is then compressed under very high pressure into a rigid body. Presently, tungsten and lead are preferred for the heavy metal and binder metal coating, respectively, although the alternative metals described above may be used. Combinations of metals may also be used. Preferably, the percentage of tungsten in the liner is within a range of approximately 99.0 % to 99.98 % by weight, although percentages within a range of approximately 90.0 % to 99.98 % may be used. The percentage of lead in the mixture is preferably within a range of approximately 0.02% to 1.0% by weight, although percentages within a range of approximately 0.2 % to 10.0 % may optionally be used.

An additional alternative embodiment of the invention uses a liner 26, which is constructed of a combination of the elements of the first two embodiments described. That is, a mixture of heavy metal powder and powdered binder metal may be used in combination with binder metal-coated heavy metal powder to construct the liner 26. The same proportions and variations in ingredients described with reference to the first two embodiments may be employed with this additional embodiment as well.

The invention has many advantages attendant with raising the percentage of heavy metal in the liner to higher levels than have been known in the art.

The embodiments shown and described above are only exemplary. Many details are often found in the art such as: types of high explosives, size and shape of shaped charges, and configuration of perforating gun assemblies. Therefore, many such details are neither shown nor described. It is not claimed that all of the details, parts, elements, or steps described and shown were invented herein. Even though numerous characteristics and advantages of the

present inventions have been set forth in the foregoing description, together with details of the structure and function of the inventions, the disclosure is illustrative only, and changes may be made in the detail, especially in matters of shape, size and arrangement of the parts within the principles of the inventions to the full extent indicated by the broad general

5 meaning of the terms used in the attached claims.

The restrictive description and drawings of the specific examples above do not point out what an infringement of this patent would be, but are to provide at least one explanation of how to make and use the inventions. The limits of the inventions and the bounds of the patent protection are measured by and defined in the following claims.